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"The impact of applying Microstrip Lines on RF power amplifiers and their assembly lines and examine how efficiency and quality is being assured"

A project submitted to Middlesex University in partial fulfillment of the requirements for the degree of Master of Professional Studies

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Table of Contents

List of Tables

List of Figures

List of Graphs

Abstract

This research work is designed to formulate a hypothesis viewing the fact that optimizing a new RF Amplifier System can result in greater efficiency with regards to saving time and saving consumption energy and costs. This is an empirical study in which the results will challenge theory and testing the experiment. The hypothesis can therefore be of further used to develop theory in this area of concern. Thus, the researcher is using his practical experience and by enhancing knowledge through literature review he will be able to comment into those factors that have caused the positive results when transforming an existing RF Amplifier component into a new active line. The research study is considered to be exploratory and descriptive and the analysis will be based on the empirical findings and the theoretical frame work for this study. Reflection is becoming part of the experiential learning throughout the researcher's work based learning studies programme and reframes his experiential learning theory. As an insider practitioner, the researcher is able to deal effectively with human resource issues and place his personal development and work success as part of the overall performance. Experiential learning is structured in the way the researcher's intentions reveal his involvement into new experiences by having intergrading his reflective observation into theories and allow to be tested out in the real world. Thus allowing the solution of the problem by participating himself into active experimentation. Reflective observation and active experimentation construct a way of transforming experience. Therefore the researcher needs to apply his abilities by studying new concepts and ideas to solve problem areas. As he is progressed through the research work based learning study the researcher is likely to build up an overall view of the phenomenon and utilize his abilities to this dimension.

CHAPTER 1

INTODUCTION TO THE STUDY

The scope of this study is to investigate the '***impact of applying microstrip lines on RF power amplifiers and their assembly lines and examine how efficiency and quality is being assured'.*** As it will be explained later, a good example for being examined includes RF power amplifiers that preferably operating below microwave spectrum and particularly in the upper VHF Band. Hence, the impact of applying microstrip lines[1]version over lumped element version has been investigated in terms of electrical properties, as well as in terms of securing the assembly and quality of the product.

1.1 Rational

As an insider practitioner, the researcher has attempted to introduce an appropriate design technique and comment upon relevant conceptual framework as to support his organization to enhance theoretical and practical knowledge. This attempt has assisted the company in overcoming competition forces with regards to new design methodology of RF power amplifiers. Specifically the researcher has investigated applications of "microstrip[1]" technology at VHF[2] (30-300MHz) power amplifiers due to its importance in the field, nowadays. The researcher's rational for investigating the "microstrip" line methodology as a special case below microwave spectrum was arising from the fact that the researcher has observed this gap in the world of RF power amplifiers but also in the published literature. Hence, the researcher was enthusiastic to proceed in filling up the gap by doing an empirical study. As a result, the project was approved by the company's management and supported with financial resources and manpower**.**

1.2 Review of Literature

By reviewing relevant literature the researcher has detected common points of view such as technical problems related to the drawbacks of lumped component applications. The review of literature has also contributed as they have been substantiated the appropriate methodologies for planning the project development. A full description of the review of literature has been dedicated for Chapter 2.

1.3 Research Approach and Experimental Learning

In the view of the researcher the methodologies which have been appropriated for this work study were the *empirical research* as well as the *experimental research*. Beyond the mentioned methodologies which have been discussed further in chapter 3, this work study has been supported by primary data, secondary data, end experimental learning from participant observations. Thus, the researcher has attempted the use of literature theory combined with his ability to gain empirical knowledge and refer to A.C Electronic Telecommunication's LTD

[1] Microstrip Lines: Printed transmission lines which can be fabricated using PCB
[2] VHF: Very High Frequency Band (30-300MHz)

resources. The study has been evaluated by promoting a group discussion within the company lines and benefit from the gathering of qualitative data. This information has been validated and confirmed the final outcome.

1.4 Technical Outline of the Impact

Technically speaking, "microstrip" technology, as a rule of thumb, is a de-facto technology used in microwave amplifiers as in very high frequency applications regular lumped components are out of specifications. Further, microwave special design lumped components are considered by most RF designers to be non affordable for mass production applications. However, in applications concerning lower frequency bands such as UHF[3], VHF, and HF[4], "microstrip" technology has come to be used partly or not used at all because most designers are still designing RF amplifiers by following the lumped element methodology. For instance, "microstrip" approach uses PCB[5] traces only. The PCB traces are transmission lines. The design procedure is based on transmission lines theory and requires a completely different way of thinking. Hence, the innovation of this study is focusing on the following parameters:

- *The impact on the technical properties (technical Specifications will be set by the company).*
- *The impact on the assembly procedures and quality assurance (assembly & testing for quality assurance according to the company's regulations based on international standards).*
- *The impact on commercial benefits overall production expenses).*

1.5 Technical Limitations of Amplifier

The study present some of the technical limitations as well as of the drawbacks of applying "microstrip" on special low frequency power amplifiers (below 55MHz) which have not been examined in this work study. This is apparently associated due to the physical length as well as the power tolerance capabilities of the lines and it becomes a very crucial factor that limits the boundaries of operation close to HF frequency Band and in high power applications. The aforementioned has been discussed further in the next chapters as it has been considered as a part of future research. The company's management and other stakeholders have been informed by the researcher about this restriction. However, the researcher was being in a position to examine these special cases for providing to the company's stakeholders official technical reports with qualitative data for future investigation. The given data was based on literature and empirical evidence during the development of the innovative amplifier.

Further, the company is supporting financially the researcher in his work study investigation regarding the availability of any new materials as well as for conducting scientific research like bending methods that will contribute to the improvement of the mentioned limitations.

1.6 Project Outcome

In completion of this study the researcher has demonstrated to his company's stakeholders and to the engineering society, through his publication, a new methodology regarding the design of RF

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[3] UHF: Ultra High Frequency Band (300-3GHz)
[4] HF: High Frequency Band (3-30MHz)
[5] PCB: Printed Circuit Board

power amplifiers. Further, until today the mentioned methodology was based on advance concepts concerning the design of microwave systems. However, by applying "microstrip" technology on a relatively lower frequency band (VHF) than microwaves was achieved quality with minimum effort, reliability in the production and commercial benefits as well as overall cost reduction in the final production. For the development of this study the researcher followed the appropriate guidance as given by the University which included the review of relevant literature, methodology, project activity, project findings and conclusion.

1.7 Historical Overview of Microstrip Lines

According to the "Proceedings of the IRE", volume 40, Dec 1952, the first "microstrip" line has been developed in 1952 by ITT laboratories and first published by Grieg and Engelmann . However, after 1960 the thin version of microstrip lines became popular exclusively on microwave applications.

Microstrip technology has become popular in the recent years due to the demand of microwave solid state amplifiers which are related to "microstrips" because they are constructed by using thin double side PCB. Such applications operate in frequencies up to (10GHz).

In the next chapter the researcher will expand his research by reviewing the relevant literature.

CHAPTER 2

REVIEW OF LITERATURE

The objective of this Project is to examine the '***impact of applying microstrip lines on RF power amplifiers and their assembly lines and look at how efficiency and quality is being assured'***. This work study is promising to the company and to stakeholders as well as to any others interested in this subject a new technical approach in the design of RF power amplifier's operating in VHF range. The aforementioned is confirming quality with minimum effort, allowing less time in production and sustaining his company's future growth and innovation. The obvious benefits of applying "microstrip" line methodology over lumped element have been estimated by the researcher based on his engineering experience and from the review of relevant literature.

2.1 Exploring Commonalities by Studying Relevant Literature

Several common aspects with this thesis are also presented in the following research publication. MYaleque RF Power Amplifiers for Wireless Communications" PH.D dissertation, Katholieke Universiteit Leuven, 2008. Thus, the scope of the author has been to analyze RF power amplifiers focusing on WIMAX[6] applications capable of operating with acceptable linearity and efficiency simultaneously. The author touches on very important aspects of wide range RF amplifiers such as the major classes of operation and matching networks. The researcher is in line with the author of the above dissertation about the uncertainty in specifications of lumped methodology. In addition, the behavior of the low and high frequency limits of lumped components according to major brand names has been investigated.

For instance, the author has specifically talked about his concern for being guaranteed the accuracy of tolerance and the self-resonance frequency of lumped0. elements which are used on his investigated WIMAX RF power amplifiers.

2.2 Technical Considerations arising by Studying Relevant Literature

From the review of the above literature (2.1) the researcher has also taken into account the electrical properties about networks formed by lumped elements compared to "microstrip" line applications in terms of the harmonic products as it is explained below:

For instance, by utilizing "microstrip" version as an impedance inverter (matching network) the researcher must take into account the frequency gap concerning the even harmonic products. By comparing the above to an identical lumped element network, it is expected to behave as a perfect low pass filter capable of suppressing both even and odd harmonics. Nevertheless this problem can be resolved by the use of the appropriate low pass filter installed at the output stage of the amplifier.

[6] WIMAX: Worldwide Interoperability for Microwave Access

2.3 Professional Considerations Arising by Studying Relevant Literature

By reviewing of relevant literature, the researcher has also deduced that RF power amplifier designers are divided in two categories:

- RF Designers (Below microwave spectrum (HF,VHF,UHF)
- Pure Microwave Designers

The design of RF power amplifiers is a common core field that belongs in the area of electrical engineering; the above may imply the plausible reasons why RF designers versus microwave designers used different methodology and technology on RF design. The researcher is convinced that both areas are different specialties. <u>Hence, the researcher is attempting to combine knowledge and methodology that is used in both areas applied on this innovation as well as to optimize a new combined methodology in the design of RF Power Amplifiers.</u>

2.4 Bibliography Related to the Design the Assembly and the Quality Assurance of the Amplifier

According to the literature review, the researcher considers appropriate design tools from the below bibliography:

<u>*Harlan Howe, Jr ‘’ Stripline Circuit Design ‘’ Artech House Inc, 1982.*</u>

Hereby, the ‘Stripline Circuit Design’ provides to the researcher powerful design tools such as the mathematical analysis of “microstrip” lines methodology in terms of the most important parameters that he must consider for his design.

In addition, the mentioned bibliography refers to the PCB’s materials as directly related with the physical length of the “microstrip” lines and the insertion loss. The importance to have the right choice of PCB material is explained below:

Double sided PCBs consist of two very thin copper layers separated by an insulator (dielectric) material. Because of the substrate material’s properties, the speed (propagation) of electromagnetic waves reduces and therefore introduces losses. Speed and loss are two different things. The above is known in electrical engineering as the propagation velocity which is calculated based on the effective dielectric constant (εr).

<u>*Thomas S.Laverghetta ‘’ Practical Microwaves’’ 1996.*</u>

After reviewing ‘Practical Microwaves’ the researcher has cultivated his knowledge on S-parameters (also known as T-parameters) and Smith Chart which are very important design tools for the implementation of the project. S parameters (scattering parameters) were first demonstrated by Kaneyuke Kurokawa of Bell Labs in 1965 as an IEEE article with title ‘’Power Waves and Scattering Matrix’’. The role of S parameters in RF design is very important. It allows the designer to solve very complicated networks by substituting the network as a simple “Black Box”.

The Smith Chart was invented by Philip H Smith. It provides electrical engineers with an important design tool to assist in solving problems with transmission lines and matching networks and it is widely used today in RF engineering.

<u>*Mini-Circuits RF/IF Designer's Handbook, Brooklyn, NY, 1997.*</u>

Mini-Circuits INC is a recognized global leader in the manufacturing of RF discrete amplifier modules which can be utilized by other manufacturers to integrate RF amplifiers. Mini circuit's handbook provides to the manufacturers very professional recommendations such as the proper assembly methodology as well as testing procedures for quality assurance in regards to their products. This handbook has been considered by the researcher as a very useful tool regarding the evaluation of assembly and testing for quality assurance.

<u>*Tricker Ray, "CE Conformity Marking" U.K, 2000.*</u>

CE marking has been published in 1993 by the European Council as the conformity marketing directive 93/465/EEC. The CE marking must be affixed on each electronic equipment that is placed in the European market for sale as it ensures that the mentioned apparatus is harmonized with all European standards. Thus, CE marking is directly related to quality assurance of a product. This literature is dedicated in testing methods that have been suggested by the European Council to confirm quality such as quality management system applications, ISO 9000, audit by the manufacturer's management system by a notified body. Reasonably, this bibliography is a strong tool for being applied in project activity (Chapters 4) but especially in project findings (Chapter5) as it concerns testing and quality assurance.

2.5 The Review of Literature Leads to the Manufacturing Methodology of the Amplifier

The researcher has completed the review of the above literature for the appropriate manufacturing methods and construction techniques which must be applied on the innovating amplifier module. For instance, the methodology sequence which must be followed is given below:

Set the desired specifications.
Design
Investigate for the availability of the components
Assembly
Testing
Evaluation.

The researcher and the company's stakeholders set the appropriate specifications of the project. As this project is the intellectual property of the company, the researcher suggests to be used on commercial basis. Thus, the specification of the innovative amplifier has been set based on the demand of the market. The researcher has been authorized to use the company's facilities for every task related to the completion of the project. The researcher must also investigate the availability of all needed electronic parts.

The researcher inspects the entire procedures from the beginning until the implementation of testing procedures. For instance, he inspects the assembly quality as it is reported by the researcher to the stakeholders. Further, the researcher inspects the quality assurance procedures in order to confirm quality. The researcher then collects all data and reports the results to the stakeholders. For this there is more explanation in the Activity Chapter.

2.6 Preview of Next Chapters

The review of relevant literature has played a very crucial role for the following chapters. For instance, the researcher describes and justifies the research approach and data collection techniques which are based on literature review (Chapter 3).

Further, the assembly and testing methodology applying on the innovative amplifier (Chapters 4&5) are based on scientific information arising partly from other author's similar projects, international standards as they have been also gathered from the review of the relevant literature.

Project findings are the documentation of the outcome with full discussion and implementation which leads to the conclusion.

CHAPTER 3

METHODOLOGY

3.1 The scope of the Chapter

The scope of Chapter 3 is to describe and justify the researcher's methodological approaches and data collections techniques which are applied for the purpose of this work study. Particular attention has been given in the following paragraphs:

- Purpose of the research
- Research Targeting
- Research Methods, data collection techniques and analysis
- Validity and reliability of the research
- The ethical nature of the research

3.2 Purpose of the Research

As mentioned in Chapter 2, through the creation of the appropriate framework, this research is currently investigating ***'The impact of applying microstrip lines on RF power amplifiers and their assembly lines and examines how efficiency and quality is being assured'***. Further, the researcher is investigating whether this microwave methodology can be successfully applied on VHF amplifiers (a non microwave application) for confirming quality with minimum effort, allowing less time in production line and sustaining his company's future growth and innovation in this application. Currently, this methodology has only been applied on microwave applications due to the fact that in VHF applications, lumped element methodology has come to be used until today. As insider practitioner, the researcher beyond the scientific impact is also investigating the effect of "microstrip" methodology in regards to the assembly & quality assurance of RF amplifiers. Hence, this professional issue has been compared with lumped element methodology for evaluation.

3.3 Modeling and Design Techniques for RF Power Amplifiers

The purpose of the project is to achieve higher levels of performance, integration, compactness, and cost-effectiveness in the design and modeling of radio-frequency (RF) power amplifiers. RF power amplifiers are important components of any wireless transmitter, but are often the limiting factors in achieving better performance and lower cost in a wireless communication system-presenting the RF design community with many challenges.

3.3.1 Academic Outcomes of the Research

This study is expected to contribute to academic knowledge through the application of a framework that created for the purpose of an understanding of the relationship between lumped element networks and "microstrip" lines as given in the example of VHF RF power amplifiers. Currently, almost all studies have distinguished both methodologies: "microstrip" has assigned exclusively for microwave designs and lumped element methodology for lower frequency spectrum applications such as VHF. The correlation between the above technologies are explained only scientifically as in real world engineering “microstrip” are printed lines made of PCB traces (non electronic parts application) and lumped elements are ordinary components (electronic parts). This framework is being adopted for the use in other frequency bands and products (filters, diplexers, splitters & combiners) thus taking this research a step ahead.

3.3.2 Practical Outcomes of the Research

A number of specific aims and objectives are being addressed for being justified by the findings are the following:

- *Less Cost Effective (Reduce the overall production budget)*
- *Good Repeatability (Consistency in specifications)*
- *Higher Production Rate*
- *More friendly in assembly procedures*
- *More friendly in testing procedures*
- *If possible, no error compensation.*

3.4 Publishing Research Outcome

Through this project, the researcher must collect qualitative and numerical data in order to defense (test the hypothesis) for the best outcome. Furthermore, he evaluates all humanitarians and ethical issues around this project. The various methodology approaches as well as data collection techniques are described in the next paragraphs. On this matter, the researcher keeps posted the company’s employees, the stakeholders as well as other external collaborators. He has also published the outcome of this research to the Cyprus Scientific and Technical Chamber magazine in October 2011 in order to disseminate the results and justify the impact. Beyond the company’s personnel, stakeholders and collaborators the researcher is confident that the findings are considered of very high importance by communication engineers (Electrical Engineers) as well as by other communication equipment manufacturers. From the aforementioned, it has been implied, that this methodology can be then adopted in projects beyond VHF applications cornering networks especially in HF Band. VHF spectrum includes applications such as DAB (Digital Audio Broadcasting), FM transmitters, DVB-T (Digital Video Broadcasting Terrestrial), Narrow Band FM transceivers etc.

3.5 Figures of Merit Leads to Technical Schedule

For the purpose of this work study, the figures of merit are related to amplifier’s efficiency, Repeatability, Variability and Reproducibility as well as the impact in assembly in terms of simplicity and testing. Each of these concepts represent a real world engineering reflection on the particular amplifier which implies a degree of innovation that leads to the ‘***impact of applying microstrip lines on RF power amplifiers and their assembly lines and examining how efficiency and quality is being assured.*** In order to evaluate the above parameters firstly needed the creation of the appropriate technical schedule versus the needed task, duration as well as manpower.

3.6 Technical Schedule for the Implementation of the Project

The researcher has stated to the involved personnel, the stakeholders and the external collaborators, about the innovation of this project and the tasks which are to be executed towards implementing. The increments are given in Table A:

Steps	Duration	Number of the involved staff
Set of the specifications	Seven business day	Researcher & Stakeholders
Design the product/materials	Seven business days	Researcher
Check for the availability of the needed Materials	Two business days	Researcher
Assembly	15 business days	Researcher& six technicians
Quality Assurance	10 business days	Researcher & six technician
Final Report	30 business days	Researcher & Stakeholders

Table A: Technical schedule for the implementation of the project

The researcher inspected each step individually and he was also applying "*Participant Observation Methodology"* during every procedure. In addition, he has received further suggestions from the involved personnel, stakeholders and collaborators. The collection of data techniques is analyzed in the next paragraph.

3.7 Research Methods, Data Collection Techniques and Analysis

3.7.1 Collection of Primary Data

Primary data have been gathered by the researcher's past professional experience as well as through past research work in similar projects. Furthermore, he is informing the stakeholders about the importance of primary data which have created the *hypothesis*. The researcher has utilized Statistical simulations concerning primary data versus secondary data targeting to a spherical estimation about the impact of the current investigation.

Further, the researcher has been interviewing the participants (Stakeholders, personnel, external collaborators) in order to establish their views about regarding any difficulties during the execution of the project and deal with ethical issues. The outcome is demonstrated in Chapter 5 (Project Findings).

3.7.2 Research Method in Designing Microstrip RF Power Amplifiers

The empirical research used is a scientific method which represents an efficient tool for modeling microstrip circuit components for RF Amplifiers. This is a way of gaining knowledge by means of direct and indirect observation or experience. The proposed project for designing RF Amplifier microstrip circuit refers to the empirical evidence being analyzed quantitatively and qualitatively. Through the quantifying of the evidence or making sense of it in qualitative form, the researcher is able to answer empirical questions, which have been clearly defined and answerable with the evidence collected data.

The project outlines the quantitative research begining with research questions which are tested through experimentation in a lab. The researcher employs in this case, a certain theory regarding the topic under investigation based on his experiences and literature gathering. Then he is testing the hypothesis. From this hypothesis, predictions about specific events are derived. These predictions then are being tested with a suitable experiment. Depending on the outcomes of the experiment, the theory on which the hypothesis and predictions were based are supported. The researcher attempts to describe accurately the interaction between the instrument and the entity being observed. If instrumentation is involved, the researcher is expected to calibrate his instrument by applying it to known standard objects and recording the results. In practice, the accumulation of evidence for or against any particular theory involves planned research designs for the collection of empirical data, and academic rigor plays a large part of judging the merits of research design.

3.7.3 Secondary Data

Secondary data is being collected by external sources such as the review of literature and from industrial application notes. Again, the researcher simulates the secondary data for evaluation. The mentioned literature review has been discussed in Chapter 2. Beyond literature, the researcher is collecting secondary data by interviewing also the external collaborators.

3.7.4 Empirical Research

The researcher considers that empirical research justifies for undertaking his project. His choice has been supported from the below:

Empirical research methodology is applied in cases which according to the hypothesis, the researcher is capable of predicting the outcome based on his personal experience of the investigated subject. In other words, the outcome has a good chance of being predicted. These predictions can then be tested with a suitable experiment and confirmed. According to A.D de Groot[1986] the empirical cycle is given below:

The validity of empirical research is supported by standardized statistical methods. For instance, the analyses of variance are fundamental to forming logical, valid conclusions. If empirical data can be verified under the proper statistical formula(s), the research hypothesis is then supported. If not, it results to a null hypothesis. A full discussion regarding the statistical support of empirical methodology has been demonstrated in Chapter 5.

The importance of empirical evidence as distinct from empirical research derived from the fact that they consisted by objective evidence that must be appeared the same regardless of the observer. For example, a thermometer will always display a certain degree of temperature for each individual who observes it. Temperature, as indicated by an accurate well calibrated thermometer, is empirical evidence. Ideally, empirical research yields empirical evidence, which can then be analyzed for statistical significance or reported in its raw form.

Given the above mentioned example for the thermometer's indications, the same principle applies on the RF amplifier's investigated parameters <u>which are objective (verified from testing) and they do not depend of the observer's opinion.</u>

Further, the A.D de Groot's empirical cycle is an ideal example of describing the researcher's approach towards the project. He has firstly observed the "microstrip" innovation on microwave applications. Thus, he has firstly estimated the innovation of "microstrip" lines applying in a lower Band VHF which offers great benefits. Thus, he has manipulated the "microstrip" technology with induction and deduction in order to optimize it in such way for being applicable in VHF Band. He has then tested the innovated amplifier and has evaluated the benefits.

3.7.5 The Link between Empirical and Experimental Research

Experimental research is applied when testing of causal process.

It is based on the manipulations of specific variables (parameters) to determine their effect on the other variables. Experimental research can be analyzed as given below:

- There is time priority in a causal relationship (cause precedes effect),
- There is consistency in a causal relationship (a cause will always lead to the same effect), and
- The magnitude of the correlation is great.

This research method is applied to Psychology, Sociology, and Social work; however, the researcher has considered this research approach links with empirical research on the following reasons:

For instance, the common denominator in this case among social work, psychology and sociology with engineering are the variables in measurements due to the operator's behavior that were testing the samples (Microstrip Amplifiers over Lumped Amplifiers). There is consequently a causal relationship as he is testing the cause i.e. weather it will always lead to the same effect regardless of the operator's behavior.

Furthermore, According to Robson (2002) this type of research involves "The assignment of an instrument under different conditions, manipulation of one or more variables by the experimenter, the measurement of the effects of this manipulation on one or more other variables and the control of all other variables". As a result, experimental research contributes to this work study very important information regarding the effect of humanitarian issues.

The above justifies the researcher's choice to use also experimental research methodology.

3.7.6 Empirical Research Has Been Supported by Statistical Quality Control Analysis

In addition to the primary collection of data the researcher employs accurate analysis of data using standardized statistical methods. This is critical as to determine the validity of the empirical research. Statistical formulas such as types of AVERAGE & RANGE (analyses of variance) are fundamental to forming logical, valid conclusions. If empirical data reach significance under the appropriate statistical formula, the research hypothesis is supported. If not, the null hypothesis is supported (or, more correctly, not rejected), meaning no effect of the independent variable(s) was observed on the dependent variable(s). The term Reliability of the collected data is very important, thus the researcher has presented the statistical definitions which have been gathered by the review of literature with numerical examples which are below:

Hence reliability is one very crucial parameter concerns quality assurance.

Reliability is defined mathematically as the ratio of the success over trials.

It can be expressed mathematically with the given formula (1) :

Reliability= success/trials (1)

For instance, 70 successes over 100 trials, the reliability coefficient results in 0.7. Furthermore, in statistics, **reliability** is the consistency of a set of measurements or of a measuring instrument, often used to describe a test. However, reliability does not represent validity. Particularly, reliability is analogous to precision while validity is analogous to accuracy. Thus, in electronics engineering applications, the manufacturers must design and test their products based on certain standards as it applies to this thesis.

On the other hand, validity refers to a conclusion or measurements that correspond accurately in the real world. For instance, calibrated instruments must be considered a very important prerequisite for the validity of measurements. As an insider, the researcher has access to the company's records about the reliability coefficient in the repeatability of lumped element amplifiers regarding the quality assurance that has been recorded until today.

Based on the so far company's records the reliability coefficient of lumped version was 0.7. The researcher is positive about the innovation that would enhance the reliability to the degree of >0.9.

Another important parameter that will be examined is the Repeatability.

Repeatability can be also verified by formula (2) as given below: *Repeatability = 5.15 R/d (2)*

Where R is the average of the ranges for all appraisers and parts

d is the number of parts the number of appraisers

3.8 Validity and Reliability of the Research

As an insider practitioner, the researcher, endeavor to complete the work-study based on the guidelines of Work Based Learning of Middlesex University. He provides evidence of personal experience and learning skills to show that conflict situations among work force can be overcome. Again, the dynamics of being an insider, allows the researcher to combine practical familiarity with the situation and being able to get literature awareness in satisfying stakeholders' goals and objectives. Some constraints and opportunities may exist where allowing a likely impact on the overall of project success. Constraints may be particularly valid in the initial stages of the research design where it is vital to be aware of the working environment's culture.

Another aspect of concern is for the researcher to clarify the distinct role of the researcher throughout the research process. Bear in mind that, the researcher as an insider is also acting in the capacity of the sole shareholder of the company. This duality of the researcher's role may be potentially conflicting and requires managing that duality in the research process.

The outcome of the research must satisfy clients, teaching groups, the University and other Professional Bodies.

Validity and reliability aspects of the research involves the researcher in measuring appropriate research questions and using legitimate methods to obtain data collection which needs to be analyzed as well in order to lead to logical conclusions and recommendations. It is also understood that a scientific paradigm must suggest that the object of study can be measured in logical way and that is possible to control variables to attain consistent results.

The proposed research is of technical issue and assembly or testing is some of the most crucial economic aspects. Furthermore, the dependence on components for building an RF block such as an RF amplifier must further investigated due to the component tolerance. For future application the researcher needs to create more robust designs as well as to make assembly line as simple as possible and adapt "microstrip" lines technology for replacing the major lumped element components on the circuit. Thus, the aforementioned expects to assist the company in becoming familiar with advance engineering knowledge in terms of technical specifications and manufacturing procedures..

3.9 The Ethical Nature of the Research

In the field of work based learning the proposed research project requires a statement and justification of research approach, project aim and methods used, rationalized from a particular point of view. Therefore, it needs to be considered of the overall moral and ethical implications of the project. The proposed project raises ethical issues arising from the research philosophical approaches used because people are directly involved. The researcher becomes aware of the issues involved and is able to respond accordingly.

Usually ethical issues arise when there is a conflict of interest either within the workforce or other stakeholders because of confidentiality or anonymity matters. The researcher is able to show an understanding of the nature of disagreements and produce results. He presents negotiating skills such as to direct conflict interest into a viable route.

The proposed project is morally and ethically appropriate. In this respect the researcher has explored all social implications like to whom it is beneficial and how it serves participants, members of the community and members of the organization. The researcher also explores all economic implications and serves interest for the stakeholders therefore there is financial gain. Lastly, the researcher examines any work environmental issues allowing participants and employees working in harmony.

Any ethical implications concerning the researcher himself have also been attended and his own ideological point of view has been considered when proceeding with the proposed project. The researcher implies a great interest in this work study as he feels is worthwhile to focus and send energy in completing the work. He rationalizes this in terms of his own ideas and views and hopes for future benefit. He takes into account his personal perspectives from one hand and the other stakeholders in the other to reconcile as to avoid conflict of interest between personal position and the ideological behavior of others.

Other implications like recognizing and understanding other professional group or community of practice have been taken into account. The researcher is aware of his responsibility to interpret ethical issues that exist within the work study. As an insider practitioner may have the company's consent when interviewing employees and assess organizational values fulfilling the expectations of the stakeholders of the proposed project.

The researcher is also aware of Middlesex ethical codes, policies and practices. He ensures that he is responsible in acting properly that safeguarding terms and guidelines laid down by the University ethical codes. The researcher acknowledges the need to obey general principles and legal requirements when undertaking this work study, such as data protection, copyrights and equal opportunities.

3.10 Summary of Chapter 3

Through Chapter 3, the researcher has presented the appropriate research methodology and the data collection techniques towards the implementation of the project. For instance, he has assigned duties to the participants based on the work schedule which is demonstrated in Table A.

Further he was interviewing the participants in order to obtain their opinion for triangulation purposes. Through the methodology approaches discussed above as well as the data collection techniques, the researcher acknowledges the scientific nature of the outcome which will be based on objective evidence. That is to say the findings can be only verified scientifically through empirical research and supported by statistical quality control. In addition, Validity and Reliability of the research methods is based on statistical analysis as it has been demonstrated in Chapter 5. Furthermore, ethical issues have also examined and analyzed according to the rules and regulations of the company and other external collaborators. In the following Chapter 4 an attempt has been made to examine the implementation of the project procedures that are based on the mentioned techniques

CHAPTER 4

PROJECT ACTIVITIES

4.1 Experimental Goal

This study was performed with two main goals in mind. The first goal was to understand and predict the *‘impact of applying microstrip lines on RF power amplifiers and their assembly lines and secondly to examine how efficiency and quality is being assured***.** For this study, these criteria were based on expert opinion and previous research. The measurements used were those most sensitive to the statistical differences between the different tasks. These evaluation criteria have been previously used for similar research purposes especially in mass engineering production export projects.

4.2 Experimental Research

To achieve the research objectives, an on-road empirical study was performed. All experimental tasks consisted of utilizing RF technical variables where by motivating an instrumented system and confronting with “microstrip” lines and “microstrip” amplifiers enabled the researcher to concurrently perform various RF designing tasks. The researcher’s primary task was to evaluate the information processing demand that secondary tasks, such as Lumped Element Version’s performance tasks and conventional tasks were adding to the RF Amplifier System primary task. Then the whole procedure was evaluating of how the system workload and situation awareness changed during exposure to the secondary tasks. The following details characterized the experiment.

4.3 Participants

The experiment was performed with the help of 12 persons divided into two different age groups. Each group consisted of six technicians with the following characteristics: (1) Educational background status, (2) more than nine years of experience, and (3) currently working with a RF Amplifier line. To recruit the participants, context of the study were sent to all employees and other 10 companies operating in Cyprus in the same area of activity calling them for their participation in the project.

The two age groups in which the participants were divided are middle age (35 - 45 years) and older persons (55 years or older). The characteristics of the participants that helped in the experiment in terms of age and years of experience have been spotted and analyzed further for the needs of the present project.

4.4 Experimental Procedure

4.4.1 Participant Screening

Companies involved: A.C Electronic Telecommunications LTD, ETS Compliance LTD, Transmitters rus LTD, ET IndustriesInc.

Participants were screened over a personal interview regarding age and engineering experience. If the participant qualified, a time was scheduled for testing. Participants were instructed to meet the experimenter at the researchers' own laboratory Center. An overview of the study was then presented to the participants. Subsequently, they were asked to complete the informed consent form and a personal questionnaire. After these steps were completed and if no problems were identified, the participant was trained on the RF Amplifier new system tasks to be performed during the experiment

4.4.2 Training

The participants were instructed on how to perform the tasks associated with the new design RF system. Sample tasks were demonstrated on cst design software. The specifications and symbols that appeared during the experiment as part of the RF Amplifier tasks were shown and explained to the participant during presentation. After training, a test was administered to determine whether the participant could identify all the specifications and symbols that were presented during the experiment. Additional training from the researcher to the participants was performed as needed. The conventional tasks were discussed during the training in the Centre lab and were repeated again once the participant adjusted to new tasks.

4.4.3 RF Amplifier System Familiarization

While the experiment was in process, the experimenter reviewed general information concerning the operation of the test. The participant was asked to operate each control and set it accordingly to lay down written specifications. When the participant felt comfortable with the procedures/ controls, the experimenter explained the assigned tasks. Once the participant was comfortable with the experiment controls and was familiarized with the new system design display, an informal hearing test was administered to determine the participant's ability to understand verbal functioning commands.

4.4.4 Probe Questioning

After each task presentation, probe questions were asked of the participants in order to recall what data he used in his decision-making process. The following presents the probe questioning that was performed after each task depending on the type of task that was performed.
Probe questioning based on the type of tasked that was performed
Task Type Questions

(1) Which categories of information did you use to perform the assembly(s)?

(2) Which categories of information did you use to make a decision?

(3) Did you perform any calculation(s), and if so what calculations?

steps	Duration	Number of the involved staff
Set of the specifications	Seven business day	Researcher & Stakeholders
Design the product/materials	Seven business days	Researcher
Check for the availability of the needed Materials	Two business days	Researcher
Assembly	15 business days	Researcher& six technicians
Quality Assurance	10 business days	Researcher & sixtechnician
Final Report	30 business days	Researcher & Stakeholders

Table A: Technical schedule for the implementation of the project

4.5 Technical Specifications of the Amplifier and Qualifications for the Assembly and Testing lines.

The researcher has informed the participants for the initiating project tasks. As an initial the researcher has set up the desired specifications relating to the amplifier's development and summons the involved personnel. As an insider, the researcher has chosen as good reference an existing lumped element amplifier because of the prehistory of this unit. On this amplifier then has applied "microstrip" technology and examined the mentioned parameters of the samples as well as the professional response of the participants.

Using secondary data collection techniques the researcher is updating a new search for gathering data from external sources (literature, application notes, and other manufacturing firms). Hence, secondary data are crossed with primary data for evaluation. Furthermore, based on his own engineering experience the researcher has confirmed RF amplifier's electrical properties (technical specifications) and standard electrical parameters for all applications. For instance, parameters such as gain, bandwidth, dissipation, power output etc, are described as properties that apply to all RF amplifiers models.

Based on literature reviewing with reference to Chris Bowick "RF Circuit Design'' [2008] 2nd edition the researcher refers to the analysis of large signal RF power amplifiers. He then is applying data through the web from NXP application notes (Major semiconductor Manufacturer) and Free-scale application notes (Major semiconductor Manufacturer) which are considered as design reference for all radio transmitter manufacturers. In addition, the researcher is using primary data gathered from inside the company's records. As the company is manufacturing RF devices for seven years, very valuable information has been kept in the records. The researcher is informing the participants of the need of finalizing the specifications. Nevertheless, the researcher is targeting on the concept of this technology for eventually being applied to all possible models. The specifications must be divided in four major categories given below:

- *Electrical Specifications*
- *Hardware Specifications*
- *Participant's Specifications*
- *Instrument Specifications*

4.6 Implementation of Technical Specifications of the Amplifier

This is a very crucial step towards the implementation of the project. The researcher is aware that the design quality determines the success of the project by all means. A fault design if not detected early, it may lead to misconception results. Thus, the researcher has defined that a successful design must fulfill the technical specifications of the unit as they have been set in the previous paragraph. The above are being verified by testing these parameters firstly. Then the other mentioned important parameters are tested as well. As an insider, the researcher is aware that a successful design must be based on the following:

- The researcher's academic background and work experience in electrical engineering/Management.
- From design methods selected by primary data from past projects
- From literature review and application notes (Secondary data)
- Research Methodology (Chapter 3)

The researcher is a Chartered Engineer and a full member of the Institute of Engineering Technology, UK since 2002 (Licensed by engineering council U.K). He is also a fellow member of Cyprus Scientific and Technical Chamber. He is an insider practitioner and director of engineering of his company. Thus, the participants feel completely trusting his abilities in engineering field and convinced that implementation of the project is expected to be of a high standard design.

It is also worth to note that the researcher has access to his company technical records i.e. the technical file of each apparatus (Primary Data).

4.6.1 Design Procedures

The researcher is gathering information from literature review from Chapter 2 and from new sources. The researcher, according to literature review, finds it very appropriate to evaluate design tools as described below:

Harlan Howe, Jr ‘’ Stripline Circuit Design ‘’ Artech House Inc, 1982

Leo G Maloratsky (Principal Engineer) Microwave & RF ‘’Reviewing the Basics of Microstrip Lines’’ March 2000

4.6.2 Evaluation of Microstrip Design Software

In this progressed phase the researcher interchanges evaluation process with the participants about the design difficulties. Microstrip methodology requires advanced electrical engineering skills as it may works negatively to be used by freshman and sophomore engineers. However, things can become simpler by the use of microstrip design software. A good question that all participants have asked and require an answer is the accuracy of the printed microstrip lines to correspond respectively to lumped networks. This procedure requires the delivery of samples which need to be prepared before production in order to have the desired results. Thus, the researcher have requested from three participants to design and test the amplifier in order to compare the outcome in the next step as it explained below:

4.6.3 Number of Testing Samples

The researcher and the participants have decided to test 10 samples of microstrip version over 10 sample of lumped version for evaluation. The researcher and the participants consider that 10 samples is a representative number to obtain good results.

4.7 Criteria for Assembly Steps and Safety Regulations

The researcher is informing the participants about the Criteria for Assembly and Safety Regulations. These are given below:

- *Print the board*
- *Etch the board*
- *Drill the board*
- *Silk Screen the board*
- *Solder.*

The safety regulations for soldering procedure have been taken by the United States Department of Labor (OSHA) and ROHS European Directive 2002/95/EC.

4.7.1 Useful component for engineering support

The researchers I sousing a printed circuit board is shown in Figure 3. This component (PCB) is the most common component in every electronic device. It is used for mechanical supporting of electronic parts using conductive pathways, tracks or signal traces. It consists of copper sheets laminated onto a non-conductive substrate. The inventor of the PCB was an Austrian engineer, named Paul Eisler, in 1936. Printing the board is a chemical procedure that the engineers transfer the pathways, tracks and signal traces from a film to the board. The film can be designed by AUTOCAD software. The next step is to remove the unwanted copper (etching the board) in order to form the pathways, tracks and signal traces from a film.

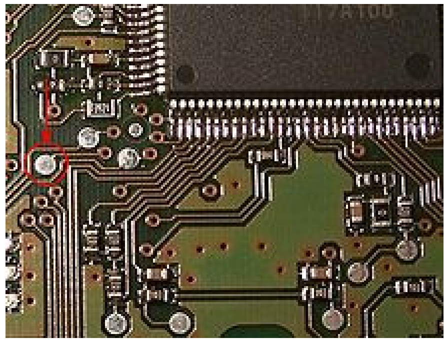


Figure 1: A sample Image of Printed Circuit Board (PCB)

4.7.2 Tasks assigned -Etching the Board

The researcher as mentioned above states that the unwanted copper must be removed in order to form pathways, tracks and signal traces from a film. This can be achieved following a chemical procedure such as iron (III)-chloride by the use of a bath. On this matter, the following are secondary data found from the internet at Wikipedia:

4.8 How Data Analysis Provide the Dependent Measures

The data analysis followed several steps: (1) consistency of data, (2) data evaluation, and (3) Average and Range method. The Average and Range method is a very friendly mathematical procedure that computes the variability of data such as whether on not they are repeatable. The data analysis process consisted of analyzing the recorded task frame by frame. This data analysis process provided the dependent measures related to start position and assigned tasks. For the other dependent measures related to performance, the data was plotted taking advantage of specialized code and statistical packages. These data, coupled with the subjective measures, were evaluated the impact of the innovation in terms of electrical engineering as well as to examine the participants' performance under each of the different tasks. Although the quantitative data is not available for these tasks, the option was a good signal that the task represents a safety line criterion to the participant if completion is attempted. At that point, a final line was reached. In respect of this, following sections discuss how the different tools and measures were employed for the data analysis of this study.
Additional points are included in Chapter 4 and 5.

4.9 Results

The results of this study comprise several types of data analysis. This chapter is divided into major sections: (1) Data Analysis of Variance based on Average and Range method recommendations), (2) Reliability, (3) Repeatability, and (4) Reproducibility. A detailed explanation of the data analysis performed in order to obtain these results is presented in Chapter 5. All the measures collected and used for the analysis of this study are presented in Tables B, C, D, and E. These tables are a quick reference for the meaning of each of the variables used throughout this section and present a detailed definition for each of the dependent measures.

4.10 Discussion

As mentioned in the Research Objective section, the primary objective of this research is to predict the '***impact of applying microstrip lines on RF power amplifiers and their assembly lines*** and secondly to examine ***how efficiency and quality is being assured.*** Thus, allowing gathering of data with the purpose of evaluating the effects of different types of tasks on the information processing demands of RF Amplifier System operations. The results that discussed in this section helped to characterize the decision-making process in information processing terms.

4.11 Chapter Summary

In this Chapter the researcher has utilized primary and secondary data and research methodology in order to set the criteria for the project. He has been advised by application notes as well as from his company regulations to set the specifications of the project. He has also informed the participants about the technical analysis of the project and they have exchanged opinions about the impact to the company.

In the next chapter (Chapter 5) are the project findings. A full analytical way of describing the development of the innovating amplifier as the proof of conformity is being discussed in chapter 5 the Project Findings. The researcher presents his results with a full discussion and implementation. By completing the assembly procedure the unit has been submitted to the quality assurance section which has been demonstrated in Table A for being confirmed that all quality standards were fulfilled. The quality assurance section can also consist of four employees that must be well trained in instrument operation. Preferably the quality assurance employee must be qualified engineers and their recommended qualifications have been demonstrated in this chapter. The inspector will provide to the quality assurance employees the expecting testing results.

Cost Effective (Reduce the overall production budget)
Good Repeatability (Consistency in specifications)
Higher Production Rate
More friendly in assembly procedures
More friendly testing procedures
If is possible, no error compensation (Troubleshoo

CHAPTER 5

PROJECT FINDINGS

Chapter 5 describes project findings with full discussion and interpretation. The comparison was between lumped element amplifiers and microstrip amplifier in order to determine the hypothesis of the project. For this, Ten samples of each type have been tested including the skills of the involved personnel based on statistical quality control methods which have been described earlier. The obtained results were focused on the following parameters:

5.1 Impact findings of applying Microstrip Lines on RF Power Amplifiers

The nature of this finding is technical oriented and it is related with the compliance in specifications as well as is related with the impact in assembly and quality assurance.

5.2 Impact findings on Assembly Lines

These findings have been determined by the impact of human interaction towards the assembly of the amplifier. According to the findings the impact was positive and it was arising by testing the time response of the assembly and it has been also confirmed through the participant's interviews. The results concerning the time response of the assembly have been plotted in Table B.

5.3 Impact findings of How Efficiency and Quality is being Assured

The impact of efficiency and quality assurance had to fulfilled by four conditions:

- Consistency in the results (stability)
- All new samples must behave identically with the original
- Regardless the appraiser's behavior must be obtained the same results.
- Significant reduction of the troubleshooting frequency which concerns the faulty units

Hence, the project findings evaluate the response of the samples based on the mentioned parameters including the behavior of the relevant involved personnel in order for the overall impact of this innovation to be finally revealed. The statistical quality control analysis is explained in 5.6 and 5.7.

5.4 Analyzing the Cost Effectiveness of the Overall Impact

The manufacturing cost of the amplifier is determined by two major parameters

- The cost of components
- The cost of production

Cost of the Amplifier = Cost of the components + Cost of the production (3)

The cost of components is a straight forward factor. However, the overall cost of the production results in other subcategories such as the *factors of production* which includes the required number of personnel for the production (*Labor Theory of Value*), the skills of the personnel, the necessary equipment as well as the overall period of time per units needed for finalizing the production as well as the quality assurance. From the aforementioned, production losses must be taken into account.
In other words, the sum of all mentioned parameters leads to the overall cost of the production.

5.5 Testing the Assembly Time Response

The researcher is counting the assembly of a "microstrip" and lumped element amplifiers. Furthermore, he has also evaluated the interaction of the involved personnel for the outcome. For instance, a single technician that utilizes the same soldering station and assembly equipment must execute both trials. The researcher is inspecting the procedure until the end. The findings are given in Table B.

Type	Number of Technicians	Period of Time per unit	Presence of Inspector
Lumped Element Unit 1	One	40 Minutes	Yes
Lumped Element Unit 2	One	38 Minutes	Yes
Lumped Element Unit 3	One	36 Minutes	Yes
Lumped Element Unit 4	One	35 Minutes	Yes
Lumped Element Unit 5	One	36 Minutes	Yes
Lumped Element Unit 6	One	34 Minutes	Yes
Lumped Element Unit 7	One	35 Minutes	Yes
Lumped Element Unit 8	One	36 Minutes	Yes
Lumped Element Unit 9	One	37 Minutes	Yes
Lumped Element Unit 10	One	38 Minutes	Yes
Average Period Of Time		**36.5 minutes**	
Total Time		**6.083 Hours**	
Microstrip Unit 1	One	15 Minutes	Yes
Microstrip Unit 2	One	13 Minutes	Yes
Microstrip Unit 3	One	10 Minutes	Yes
Microstrip Unit 4	One	13 Minutes	Yes
Microstrip Unit 5	One	11 Minutes	Yes
Microstrip Unit 6	One	9 Minutes	Yes
Microstrip Unit 7	One	8 Minutes	Yes
Microstrip Unit 8	One	10 Minutes	Yes
Microstrip Unit 9	One	8 Minutes	Yes
Microstrip Unit 10	One	8 Minutes	Yes
Average Period Of Time		**10.5 minutes**	
Total Time		**1.75 Hours**	

Table B: Assembly Response of Lumped Element over Microstrip

5.5.1 Implementation of the Assembly. Time Response

As already discussed in the Activity Chapter the technician begins the assembly under the inspection of the researcher. During the assembly the researcher is discussing with the assembler and with the observers their impression regarding this trial. In this respect the researcher has observed that the assembler was less confident with the lumped element version as it will be explained below:

After the trials have completed, the researcher plotted the results in Table B. Furthermore, according to the collected primary data in Table B, it has been obvious that “microstrip” methodology enhance the assembly performance of the assembler comparing to the lumped element methodology. For instance, a single technician (assembler) requires 6.083 hours to assembly 10 lumped element amplifiers versus 1.75 hours to assemble 10 “microstrip” amplifiers. The average time for each unit to be assembled (according to Table B) is 36.5 minutes for a lumped elements unit and 10.5 minutes for a “microstrip” version unit. The researcher illustrates the results of Table B to the participants. He is also interviewing the assembler and the observers and he confirms their consent regarding the results.

The assemblers have stated:
During the assembly of a lumped element amplifier an assembler must:

- Gather the appropriate components, such as inductors and capacitors, as these are the required parts of the circuits.
- Before soldering each component he has to confirm by observation the value of the component as well as to determine the position that must be soldered
- He has to spend time soldering all needed components on the printed circuit board
- He has to check for bad connections and short circuit before submit the amplifier for testing.

It appears that lumped element procedure is time consuming for being executed. According to the assemblers who executed the trials, they have also commented that “microstrip” amplifiers are not based on discrete components resulting in faster assembly.
Five other assemblers has executed the same procedure with similar results with Table B

5.6 Measuring the Reliability in Respect of How Efficiency and Quality is being Assured

The researcher is now examining the reliability of lumped element versus “microstrip” such as of obtaining consistency results. The reliability for consistency is a factor which is directly related to the quality assurance of the amplifier. For example, if a tested sample amplifier provides reliable results, it implies that any copy of this amplifier will inhibit the same properties as the original. The variables which could affect this performance are analyzed in the next paragraphs. In addition, a repeatable amplifier does not require error compensation since it complies with the quality assurance requirements. Reliability can be estimated by statistical approaches through the empirical research by testing the sample amplifiers and compare their specifications with a reference. Most important parameters for being evaluated are given below:

- Power Output (The power output on the load)
- Bandwidth (Frequency range that the amplifier maintains the desired specifications)
- Gain (The ratio of the output power to the input power)
- Efficiency: (The ratio of the RF power output to the power supply dissipation)
- Harmonic Rejections: (Even and odd multiples of the fundamental frequency)

(Efficiency can be also translated in terms of thermal dissipation as it is the deduction of the power supply dissipation – RF Power Dissipation.)
Beyond the company’s regulations, a reliable source concerning the testing methodology (secondary data) can be based on European Directives, particularly from European Telecommunications Standards Institute (ETSI). This organization is responsible to provide the European directives to the manufacturers in order to design their products to comply with CE[8] Marking.[7]

7 EN 302018: Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Transmitting Equipment for the Frequency Modulated (FM) Sound Broadcasting Services.

According to ETSI, the appropriate directive is **EN 302018** [7] **V.1.2.1(2006-03)**

5.6.1 The Criteria for Compliance

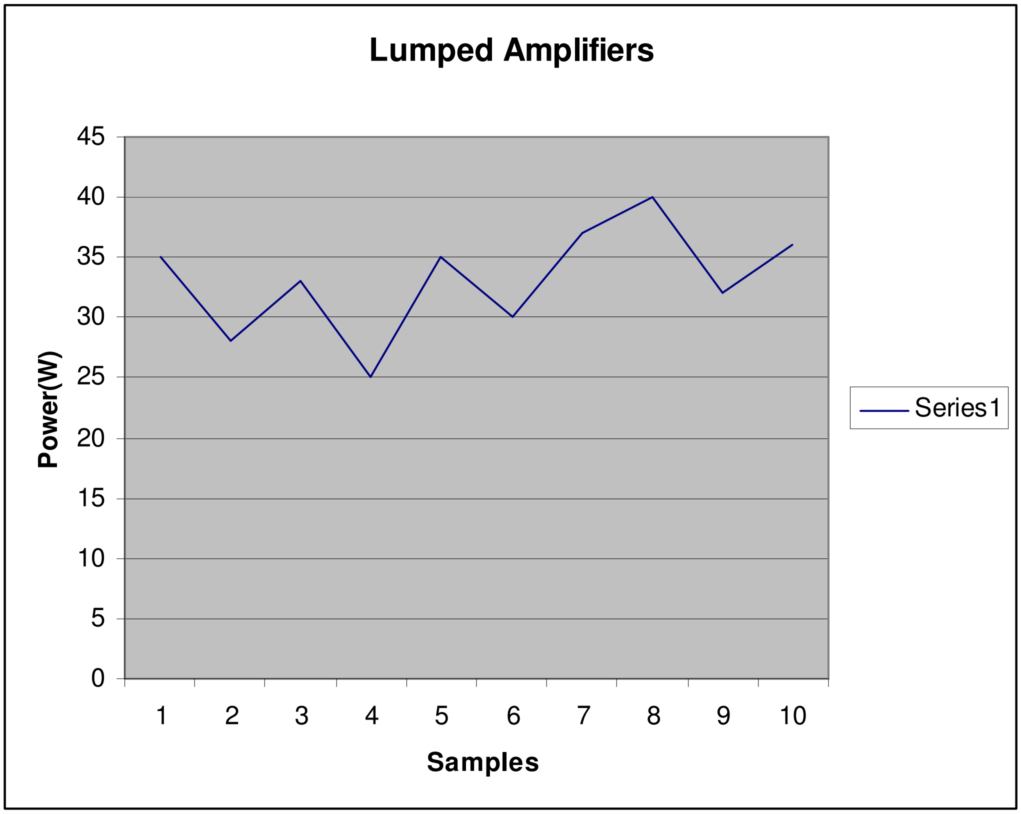
- Power output $\geq$ 35W The power output capabilities of the amplifier
- Bandwidth $\geq$ 15% The frequency range that the amplifier sustains its specifications
- Gain $\geq$ 10dB The ratio of output power versus the input power
- Efficiency $\geq$ 60% The ratio of the output power versus the power dissipation
- Harmonic (2^{nd}) $\geq$ -60dB The Even multiple of the fundamental frequency
- Harmonic (3^{rd}) $\geq$ -70dB The odd multiple of the fundamental frequency
- The testing engineer must be qualified with 5 years of experience in testing.

Amplifier Type	Power Output	Bandwidth Center Frequency=98MHz	Gain	Efficiency	Harmonic 2nd	Harmonic 3rd	COMPLY
Lumped Element 1	35W Reference	20%	13dB	65%	65dB	75dB	YES
Lumped Element 2	28W	15%	9dB	56%	55dB	62dB	NO
Lumped Element 3	33W	15%	11dB	60%	60dB	70dB	YES
Lumped Element 4	25W	10%	8dB	52%	50dB	55dB	NO
Lumped Element 5	35W	19%	12dB	64%	60dB	65dB	YES
Lumped Element 6	30W	17%	10dB	62%	65dB	72dB	NO
Lumped Element 7	37W	22%	13dB	68%	65dB	70dB	YES
Lumped Element 8	40W	24%	13dB	70%	65dB	68dB	YES
Lumped Element 9	32W	19%	12dB	64%	58dB	64dB	NO
Lumped Element 10	36W	21%	13dB	66%	60dB	65dB	YES

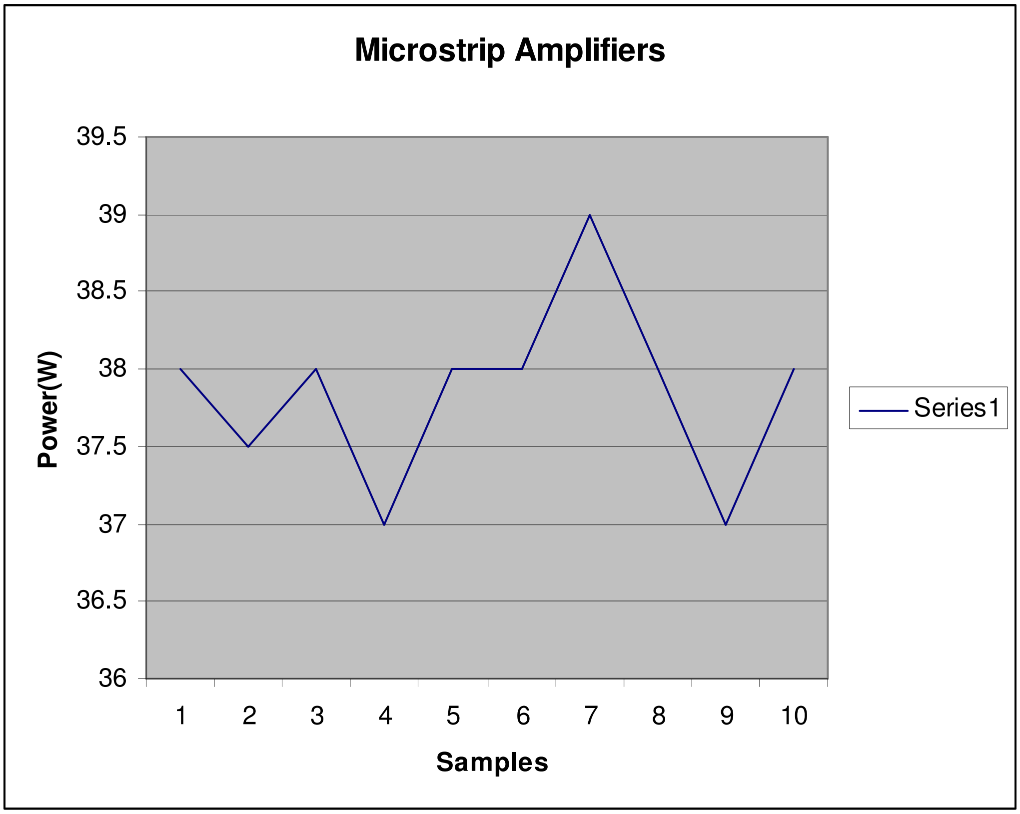
[8] CE: It is a mandatory conformity mark for product placed in European Market

Average Tolerance	**3.77W**	**3.50%**	**2.83dB**	**4.5%**	**5.7dB**	**9.3dB**	**9.3dB**
Microstrip Ampliier 1	38W reference	25%	14dB	68%	65dB	75dB	YES
Microstrip Ampliier 2	37.5W	25%	14dB	69%	65dB	75dB	YES
Microstrip Ampliier 3	38W	25%	14dB	68%	66dB	75dB	YES
Microstrip Ampliier 4	37W	23%	14dB	68%	65dB	75dB	YES
Microstrip Ampliier 5	38W	25%	14dB	65%	65dB	75dB	YES
Microstrip Ampliier 6	38W	25%	14dB	68%	64dB	77dB	YES
Microstrip Ampliier 7	39W	26%	14dB	68%	65dB	75dB	YES
Microstrip Ampliier 8	38W	25%	14dB	67%	65dB	75dB	YES
Microstrip Ampliier 9	37W	25%	14dB	68%	65dB	73dB	YES
Microstrip Ampliier 10	38W	25%	14dB	68%	65dB	75dB	YES
Average Tolerance	**0.38W**	**0.33%**	**0%**	**0.5%**	**0.22dB**	**0.22dB**	

Table C: Testing Results of Technical Specifications



Graph 1: The Ripple of the Power Output (Lumped Version)



Graph 2: The Ripple of the Power (Microstrip Version)

The researcher illustrates Table C to the participants. He discusses the data variations between the two technologies (lumped element, microstrip). Based on statistical analysis from Chapter 3, the reliability coefficient can be calculated based on the following approach:

5.6.2 Measuring the Reliability Coefficient Based on Data of Table C.

- Lumped Element Samples
- Number of Trials: 10
- Number of tested samples: 10
- Appraisers: One
- Success: 6 Samples

Reliability= success/trials (4)

Hence, for the lumped element (10 samples) the researcher had 10 trials over 6 successes.

The reliability coefficient is then 0.6.

For the “microstrip” version (10 samples) the researcher had 10 trials over 10 successes.

Hence, the reliability coefficient is then 1.

The aforementioned is also justified the reliability coefficient of the primary data that was taken from the company’s records concerning the production of lumped element amplifiers until today, as it has been mentioned in Chapter 3 . The reliability coefficient until today was 0.7.
The researcher and the quality assurance engineer have discussed the results of Appendix 3 and report them all to the participants. The researcher has supported further the results of the tested samples by analyzing the variables that affect both amplifiers.

5.6.3 Variables that Effect Lumped Element Version’s Performance

The majority of the components that dominate a lumped element amplifier are capacitors and inductors.

Hence, there are five major factors (Variables) that they will affect the tolerance in specifications of any lumped element amplifier. The variables are given below:

- The tolerance of the capacitors (basically effect the tuning circuits)
- The tolerance of the inductors (Basically effect the tuning circuit)
- The tolerance of due to the soldering of the above components
- The tolerance of the semiconductor (Transistor, Mosfet)
- The Printed Circuit Board Dielectric Constant

5.6.4 Variables Affect Microstrip Version

The microstrip version is much simpler in construction that the lumped element as it is effected only by two major variables as given below:

- The tolerance of the printed circuit board (dielectric constant)
- The Semiconductor (Transistor Mosfet)

It is obvious that only two main variables affect the reliability of microstrip version. The common variables in both technologies though are the tolerance of the semiconductor (Transistors) and the dielectric constant of the PCB which can be detected by the manufacture’s data sheet. In addition, Printed circuit boards are very reliable in specifications as they are made of standard materials and tolerance can be also detected by the data sheet. Thus, for a good quality PCB the tolerance is considered insignificant.

5.7 Reproducibility in Measurements Confirms Quality Assurance

The researcher is now informing the participants about the concept of Repeatability, Variability and Reproducibility. Due to the fact that all of the mentioned testing procedures have been executed by one appraiser, the researcher is analyzing to the participants the **Average and Range Method** which concerns Repeatability, Variability and Reproducibility of measurements**.** For instance, the samples must be tested at least twice by more than one appraiser in order to be determined the reproducibility of the data results. Hence, Reproducibility is the variations in measurements which caused by the differences in operator’s behavior.

The researcher is demonstrating all of the above concepts by presenting a seminar.
He is reviewing empirical and experimental research from Chapter 3 as given below:
Experimental research is applied when testing of causal process.

It is based on the manipulations of specific variables (parameters) to determine their effect on the other variables. Experimental research can be analyzed as given below

- There is time priority in a causal relationship (cause precedes effect),
- There is consistency in a causal relationship (a cause will always lead to the same effect), and
- The magnitude of the correlation is great.

The researcher is analyzing the concept of Repeatability as data consistency and stability. Further, the variation in data analysis is defined as the Variability. The researcher will quantify Repeatability and Reproducibility using ***Average and Range Method*** in order to support the empirical research. The mentioned method must be utilized by 10 parts, 3 appraisers and 2 trials. Thus, the researcher is presenting new trials for Appendix 3 concerning microstrip amplifiers. In other words the researcher endeavors to provide evidence regarding the Repeatability and Reproducibility of the data:

Following Average and Range recommendations :

Number of Samples: 10 microstrip amplifiers.

Number of Testing Engineers : Two qualified engineers 5 years of testing experience

Number of trials : One (as the previous testing counts as one more trial)

Criteria of Compliance:

- Power output $\geq$ 35W The power output capabilities of the amplifier
- Bandwidth $\geq$ 15% The frequency range that the amplifier sustains its specifications
- Gain $\geq$ 10dB The ratio of output power versus the input power
- Efficiency $\geq$ 60% The ratio of the output power versus the power dissipation
- Harmonic (2^{nd}) $\geq$ -60dB The Even mulitiple of the fundamental frequency
- Harmonic (3^{rd}) $\geq$ -70dB The odd multiple of the fundamental frequency

Amplifier Type	**Power Output**	**Bandwidth** Center Frequency=98MHz	**Gain**	**Efficiency**	**Harmonic 2nd**	**Harmonic 3rd**	**COMPLY**
Microstrip Ampliier 1	38W reference	25%	14dB	68%	65dB	75dB	YES
Microstrip Ampliier 2	38W	25%	14dB	68%	65dB	74dB	YES
Microstrip Ampliier 3	38W	25%	14dB	68%	64dB	76dB	YES
Microstrip Ampliier 4	37W	23%	14dB	68%	66dB	75dB	YES
Microstrip Ampliier 5	38W	25%	14dB	65%	65dB	75dB	YES
Microstrip Ampliier 6	38W	25%	13dB	68%	64dB	75dB	YES
Microstrip Ampliier 7	38W	25%	14dB	68%	65dB	75dB	YES
Microstrip Ampliier 8	38W	25%	14dB	65%	65dB	77dB	YES
Microstrip Ampliier 9	37W	25%	14dB	68%	65dB	75dB	YES
Microstrip Ampliier 10	38W	25%	14dB	68%	65dB	75dB	YES
Average Tolerance	**0.22W**	**0.22%**	**0.11%**	**0.66%**	**0.33dB**	**0.44dB**	

Table D. Re-Testing of Microstrip Amplifier by Appraiser 1

Amplifier Type	Power Output	Bandwidth Center Frequency=98MHz	Gain	Efficiency	Harmonic 2nd	Harmonic 3rd	COMPLY
Microstrip Ampliier 1	38W reference	25%	14dB	68%	65dB	75dB	YES
Microstrip Ampliier 2	37W	25%	14dB	69%	65dB	76dB	YES
Microstrip Ampliier 3	37W	25%	13dB	65%	66dB	75dB	YES
Microstrip Ampliier 4	37W	23%	14dB	68%	63dB	75dB	YES
Microstrip Ampliier 5	38W	27%	14dB	65%	65dB	75dB	YES
Microstrip Ampliier 6	38W	25%	13dB	67%	64dB	76dB	YES
Microstrip Ampliier 7	38W	26%	14dB	68%	65dB	75dB	YES
Microstrip Ampliier 8	38W	25%	12dB	67%	68dB	77dB	YES
Microstrip Ampliier 9	37W	22%	14dB	68%	65dB	73dB	YES
Microstrip Ampliier 10	38W	25%	14dB	68%	65dB	75dB	YES
Average Tolerance	**0.44W**	**0.88%**	**0.44%**	**1%**	**0.77 dB**	**0.66dB**	

Table E: Re-Testing of Microstrip Amplifier by Appraiser 2

The researcher has inspected the trials presented in Tables D, Tables E. He informs the participants about the results which have not been influenced by the behavior of the operator. The above procedures have demonstrated the validity of measurements. The researcher has proceeded to an interview of the participants who have declined the following:
Through testing procedure it has been proved the consistency of the specifications of the "microstrip" amplifier. The aforementioned relieve the technicians from troubleshooting the faulty amplifiers as well as the most importantly the technicians do not feel time pressure for completing the quality assurance.

5.8 Review of Findings

The researcher presents a summary of the results to the participants as given below :
He has initially examined the assembly rate between lumped element and microstrip amplifiers and the results were given in Table B. For instance, the average period of time for a single assembler to construct a lumped element amplifier was 36.5 minutes in contrast to the microstrip amplifier which required only 10.5 minutes. Further, the entire involved personnel were positive that microstrip methodology was much simpler in assembly than lumped methodology.

The next step was to determine the ''Measuring Procedures for the Reliability of Obtaining Repeatable Results''. The researcher has set the criteria for compliance and he has followed the testing methodology according to ETSI organization.
The findings were demonstrated in Table C. He illustrates that over 10 lumped element samples only six have complied in contrast to microstrip which they all have complied.
Final step was to determine the Repeatability Variability and Reproducibility in Measurements of the microstrip amplifiers by the use of Average and Range Method. The data results were given in Table D, and E. This method examines the variations in measurements caused by the operator's behavior. The findings have confirmed that small variations due to the operator's behavior have not affected the quality. The participants were enthusiasm and they stated about lumped version problems that they have encountered such as for troubleshooting faulty units to overcome the technical problem in regards to the time pressure.
The findings are further analyzed in Chapter 6 in the Conclusions and Recommendations chapter.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The researcher has completed his work study successfully and through his findings has demonstrated to the participants, the stakeholders, the involved personnel and collaborators, the <u>impact of applying microstrip lines on RF power amplifiers and their assembly lines and examined how efficiency and quality is being assured</u>.

The researcher has based his research on primary data obtained by the company's records, secondary data collected from the review of relevant literature, and finally by obtaining empirical evidence through his research. By reviewing the relevant literature, the researcher was confident in a degree of accuracy for the expecting results of the innovation. In addition, based on his engineering experience in the area of electrical engineering was able to support the findings. The review of relevant literature has also been contributing useful knowledge which may be applied for future project in respect of the analysis of "microstrip" lines and "microstrip" amplifiers. More technical aspects regarding the design of "microstrip" amplifiers can be found in the Appendices.
Hence, his work study has included two major research methods as they have explained in Chapter 3 such as the Empirical research and the Experimental research. Further, he has also based his primary and secondary data as well as empirical findings by applying participant observation.
The researcher has suggested of adapting empirical research methodology because it is applied in cases which according to the hypothesis the researcher is capable of predicting the outcome. In other words, the outcome has a good chance of being predicted because it is based on objective evidence. These predictions can then be tested with a suitable experiment and confirmed as it has been done. Further the researcher has introduced to the participants the A.D de Groot's empirical cycle which consists of five sections as given below:

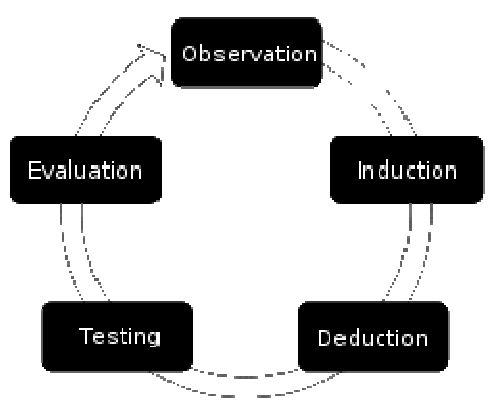


Figure 2: A.D de Groot empirical cycle

Further he supported validity and reliability of his work study by utilizing statistical analysis such as by executing the inspection of the appropriate trials. He has also set the number and the qualifications of the appraisers for being able to estimate the production rate as well as the reliability coefficient between the lumped element traditional amplifiers and the microstrip amplifiers that confirm the quality. In order to execute the aforementioned, he has set the criteria for compliance according to his company's technical and ethical regulations. For instance, he set the desired technical specifications of the samples and the required qualifications of the involved personnel. Further, he has been advised by reviewing the European Directives which are demonstrated by ETSI organization for the optimum testing methodology as it has been demonstrated in Chapter 3.

In addition, he has proceeded further to the determination of the Repeatability, Variability and Reproducibility of the findings by the use of Average & Range Method by examining the behavior of operators in relation to the variations of the findings. The following is an abbreviated explanation using the method recommended by the AIAG, (Automotive Industry Action Group). It is used in most quality plans including six sigma and ISO9000. Hence he has also combined empirical research with experimental research which is applied when testing of causal process as explained below:

It is based on the manipulations of specific variables (parameters) to determine their effect on the other variables. In this case the manipulated variables are the technical specifications of the amplifiers whether or not have been affected by the difference of the appraisers' behavior. Experimental research can be analyzed as given below:

- There is time priority in a causal relationship (cause precedes effect),
- There is consistency in a causal relationship (a cause will always lead to the same effect), and
- The magnitude of the correlation is great.

More specifically, Reproducibility is related to the variations in measurements which caused by the differences in operator's behavior. The researcher has demonstrated to the participants that the difference in operator's behavior can still sustain the desired results as the data deviation is very small to affect the final result. He has discussed with the involved personnel (assemblers, testing engineers) regarding his findings in order to get their consent for the results.

Hence, his work study for the "*The impact of applying microstrip lines on RF power amplifiers and their assembly lines and examining how efficiency and quality is being assured"* can insinuate the below :

Impact of applying microstrip lines on RF power amplifiers:
- Less Cost Effective (Reduce the overall production budget)
- Reliability of Obtaining Repeatable Results (Consistency in specifications)

The Impact on Assembly Lines:
- More friendly in assembly procedures
- More friendly testing procedures

The Impact of How Efficiency and Quality is being Assured:
- Higher Production Rate
- No need for error compensation as the overwhelming majority of the units will comply.

All of the above parameters have been substantiated in chapter 5 without any ethical conflict between the involved personnel, the stakeholders and the collaborators. Thus, the final concussion can be stated as follows:

The dominant factor which determines the success of “microstrip” amplifier is based on the design. As they are printed lines, their physical length and width are very difficult to reshape manually for error compensation at a specific prototype sample. This implies a designer with a certain advance level in electrical engineering to execute the design or alternatively to be used good quality software. Otherwise, one must proceeding in the development of numerous samples (Trial & Error) until reaching the optimum results. A tested compliant sample promises that any copy will provide consistency in specifications; it allows significantly less time to be constructed, thus increases the production rate and production efficiency. Hence the innovation is directly related to the cost effectiveness of the unit for mass production. On the other hand, lumped element amplifiers are based exclusively on lumped components. The aforementioned allows the technician to optimize the sample’s specifications by replacing the wrong estimated components (Trial & Error) as may be technicians get settled in this. However, a compliant unit does not promise consistency in specifications due to the tolerance of lumped element components as well as because of the other drawbacks which have been observed in the findings. If a technician is testing lumped element amplifiers, it is confirmed that he must proceed for error compensation frequently as the reliability coefficient was found 0.6 in case of mass production it will be a production disaster. However, for very low production rates or custom made products, lumped element technology can be supported.

CHAPTER 7

FUTURE CONSIDERATIONS

Through this work study, it has been demonstrated that the impact of the innovative amplifier technical specifications has affected positively a plethora of other parameters associated with the functionality of the company. Thus, this work study has paved the way for further research in more complicated applications concerning “microstrip” technology. For instance, the innovative amplifier which has been examined in this work study can be categorized as a medium power version; hence the researcher is now confident for suggesting the examination of high power versions such as push-pull amplifiers. For the sake of the argument, push-pull amplifiers consist of two identical (Gemini) transistors that have been designed for doubling the power output; thus, they are very popular nowadays. A high power push-pull RF amplifier is comprised by balun which is constructed by semi rigid transmission lines. Hence, a future challenge is to replace it by “microstrip” lines. Baluns are considered an integral part of a push-pull RF power amplifier.

In addition, further investigation may be conducted in HF bands. Due to the long wavelength, “microstrip” lines become very impractical if we embraced the existing “microstrip” technology. The researcher’s challenge is to execute further research for tapering “microstrip” lines in order to operate efficiently in HF Bands.

The innovation of this research has been published by Cyprus Scientific and Technical Chamber in October 2011 and it is given in the appendix on page 46. The researcher is targeting for more future publications on this major. In addition, concerning other future applications, the researcher will apply this microstrip innovation in order to enhance the efficiency and ruggedness of the final stage in digital Radio and TV amplifiers which his company will be manufacturing in the near future. On this matter, the project has been approved for funding by Research Promotion Foundation (RPF) in November 2011

Besides all the mentioned technical aspects, the important point that has been arisen by this work study is the impact around the innovation as it has been demonstrated in the previous chapters.

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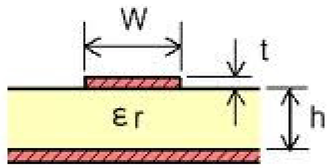
Appendix

The impact of applying microstrip lines on RF power amplifiers and their assembly lines and examining how efficiency and quality is being assured has been published by Cyprus Scientific and Technical Chamber October 2011

Η τεχνολογία "Microstrip Line" (τυπωμένη γραμμή μεταφοράς) έχει αναπτυχθεί το 1952 από τα εργαστήρια της ITT. Η καινοτομία αυτή είχε δημοσιευθεί την εποχή εκείνη από τους μηχανικούς Grieg και Engelmann. Σήμερα η τεχνολογία "Microstrip Line" χρησιμοποιείται ευρέως μόνο στις μικροκυματικές εφαρμογές όπως σε συντονισμένα κυκλώματα ενισχυτών καθώς επίσης και σε άλλες εφαρμογές παθητικών δικτύων οι οποίες δεν θα εξεταστούν σε αυτή την δημοσίευση. Τα "Microstrip Lines" ανήκουν ουσιαστικά στην κατηγορία των γραμμών μεταφοράς υψηλών συχνοτήτων όπως π.χ. το ομοαξονικό καλώδιο. Η βασική διαφορά ενός ομοαξονικού καλωδίου από μια γραμμή Microstrip, βρίσκεται στην κατασκευή. Το ομοαξονικό καλώδιο αποτελείται από δύο ομόκεντρους κυλινδρικούς αγωγούς διαφορετικής διαμέτρου, που στηρίζονται σε απόσταση ακριβείας σε όλο το μήκος της γραμμής λόγω του μονωτικού του που ονομάζεται διηλεκτρικό. Το "Microstrip Line" περιγράφεται σαν μια αγώγιμη λωρίδα, (στις πλείστες περιπτώσεις χάλκινη) με βασικό πλεονέκτημα ότι αποτελεί μέρος του τυπωμένου κυκλώματος της πλακέτας διπλής όψεως. Τα δύο χάλκινα επίπεδα της πλακέτας είναι εγκατεστημένα σε απόσταση ακριβείας πάνω στο διηλεκτρικό(εr) που βρίσκεται στο ενδιάμεσο. Ως αποτέλεσμα η λωρίδα τυπώνεται πάνω στη μία όψη της πλακέτας και σχηματίζεται με την μέθοδο της χαρακτικής, η δεύτερη χάλκινη όψη παραμένει ανέπαφη ώστε να αποτελεί την γείωση της γραμμής, όπως φαίνεται στο πιο πάνω σχήμα. Συνεπώς, όπως όλες οι γραμμές μεταφοράς, έτσι και η γραμμή "Microstrip" παρουσιάζει ιδιότητες συντονισμένου κυκλώματος, τέτοιες ώστε να καθίσταται δυνατή η αντικατάσταση σωρείας χωρητικών και επαγωγικών συγκεντρωμένων στοιχείων (Lumped Components) που περιλαμβάνονται στα συντονισμένα κυκλώματα προσαρμογής και στα φίλτρα αποκοπής αρμονικών που είναι αναπόσπαστο μέρος των ενισχυτών υψηλών συχνοτήτων HF,VHF σήμερα. Πολύ συχνά οι αναγραφόμενες προδιαγραφές των εν λόγω συγκεντρωμένων στοιχείων αποκλίνουν από τις πραγματικές. Ως αποτέλεσμα, η διαδικασία συναρμολόγησης των εν λόγω ενισχυτών καθίσταται χρονοβόρα και περίπλοκη σε σχέση με την διασφάλιση της ποιότητας και την αναπαραγωγή τους. Η κλασσική μεθοδολογία "Microstrip Line" δεν εφαρμόζεται στις μπάντες συχνοτήτων HF,VHF ώστε να βελτιστοποιηθούν τα πιο πάνω, εξαιτίας του μεγάλου μήκους κύματος των εν λόγω συχνοτήτων που είναι άμεσα ανάλογο με τις φυσικές διαστάσεις της γραμμής Microstrip. Στις μπάντες συχνοτήτων «HF, VHF,» συμπεριλαμβάνονται οι εκπομπές από το ψηφιακό ραδιόφωνο, το αναλογικό ραδιόφωνο, την αεροναυσιπλοΐα κλπ .



Παρόλα ταύτα, κατόπιν ανασκόπησης της σχετικής βιβλιογραφίας, καθώς επίσης εμπειρικής και πειραματικής έρευνας, έχει τεκμηριωθεί πως η μεθοδολογία "Microstrip" θα μπορούσε να αναπροσαρμοσθεί με επιτυχία στους ενισχυτές, «HF, VHF,», προσφέροντας πολύ σημαντικές βελτιστοποιήσεις οι οποίες θα αναπτυχθούν παρακάτω: Η έκταση του κειμένου δεν επιτρέπει να παρουσιαστεί ο μαθηματικός συλλογισμός της καινοτομίας λόγω περιορισμού, παρόλα ταύτα παρουσιάζονται τα ευρήματα της μελέτης σε συνοπτική μορφή.

Βάση της σχετικής μελέτης ενδείκνυται ότι η μεθοδολογία "Microstrip Line" είναι σαφώς ανώτερη των "lumped components" δια τους πιο κάτω λόγους:

- Βελτιστοποίηση στις τεχνικές προδιαγραφές του ενισχυτή (Μείωση απωλειών)
- Ταχύτερη συναρμολόγηση του ενισχυτή (Ελαχιστοποίηση των εξαρτημάτων)
- Βελτιστοποίηση στην επαναληψιμότητα (Μικρή απόκλιση προδιαγραφών)
- Μειώνεται δραματικά το συνολικό κόστος παραγωγής.

Από το πιο πάνω συνεπάγεται ότι ένας ενισχυτής υψηλών συχνοτήτων "Microstrip Line", θα χρειαζόταν ελάχιστα πρόσθετα εξαρτήματα για να ολοκληρωθεί, έτσι που η διαδικασία συναρμολόγησης του, να γίνεται απλούστερη και ταχύτερη. Σε αντίθεση με το γεγονότος ότι κάθε παρτίδα χωρητικών και επαγωγικών συγκεντρωμένων στοιχείων παρουσιάζει τα προαναφερθέντα προβλήματα προδιαγραφών, η επανάληψιμοτητα στην παραγωγή ενισχυτών HF, VHF διασφαλίζεται υιοθετώντας την τεχνολογία "Microstrip Line" σύμφωνα με τις πιο πάνω βελτιστοποιήσεις. Βάση εργαστηριακών μετρήσεων, ενδείκνυται επίσης ότι ο συντελεστής εγκυρότητας και επαναληψιμότητας στην παραγωγή των ενισχυτών «lumped components ανέρχεται < 0.7 ενώ της τεχνολογίας "Microstrip Lines", ανέρχεται στο > 0.9. Επιπρόσθετα, η ίδια ερεύνα καταδεικνύει ότι η διαδικασία συναρμολόγησης ενισχυτών με "Microstrip Lines" θεωρείται μέχρι 200% ταχύτερη, απλούστερη και ακριβέστερη από τους ενισχυτές με "lumped components". Η εγκυρότητα στην αξιοπιστία των ευρημάτων της παρούσας μελέτης, έχει υποστηριχθεί από την γνωστή μέθοδο "Average and Range Method".

Appendices

General Specifications

Electrical Specifications of the Amplifier

Bandwidth	87.5-108MHz
Gain	12dB
Power Output	35W
Class	AB
Efficiency	65%
Drain Voltage	15VDC
Dissipation	75W

Instruments used:

Spectrum Analyzers: ADVANTEST U3751, ROVER DL1-DIGILINE
Impedance Analyzers: MFJ- 259B
Power VSWR meter: BIRD 43
Power Supply: MEANWELL SP-150-15
Multimeter: PUCTEC MY64
Hardware Specification.
PCB Material: Epoxy FR4
Thickness: 0.8mm
PCB: Double Sided
Notes: PCB (Printed Circuit Board)

The needed constructing Materials

PCB (Prototype Circuit Board)
Lumped Components: Inductors, capacitors, Resistors, Chokes
PCB (Prototype Circuit Board)
Semiconductor Device

Appendices

TESTING SET UP
EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUDE

A.1.1 Testing arrangement for monophonic transmitters

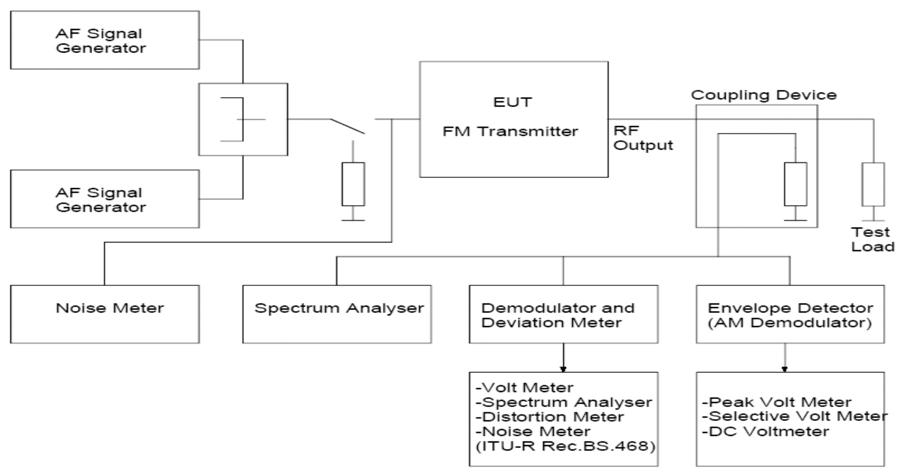
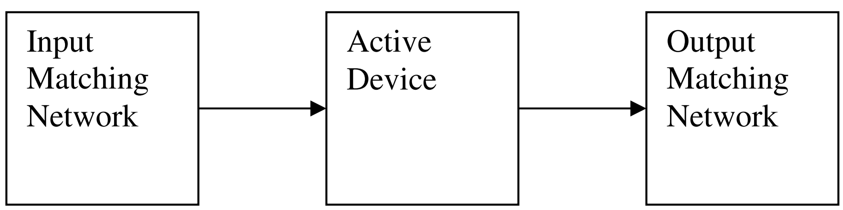


Figure A.1: Testing arrangement for monophonic transmitters

Appendices

TYPICAL BLOCK DIAGRAM OF RF AMPLIFIERS



Appendices

REALIZATION

INNOVATIVE PROTOTYPE PLANAR AMPLIFIER VERSUS LUMPED ELEMENT